DESIGN OF A LONG SPAN TRANSFER BEAM (REINFORCED CONCRETE) AND THE MODE OF CONSTRUCTION AND REMOVAL OF SCAFFOLDING TO CATER TO THE TRANSFER BEAM

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CIVIL ENGINEERING

UNIVERSITI TEKNOLOGI PETRONAS

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By

MOHD ASFIRDAUS BIN ASRI

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Submitted to the Civil Engineering Programme

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CERTIFICATION OF APPROVAL

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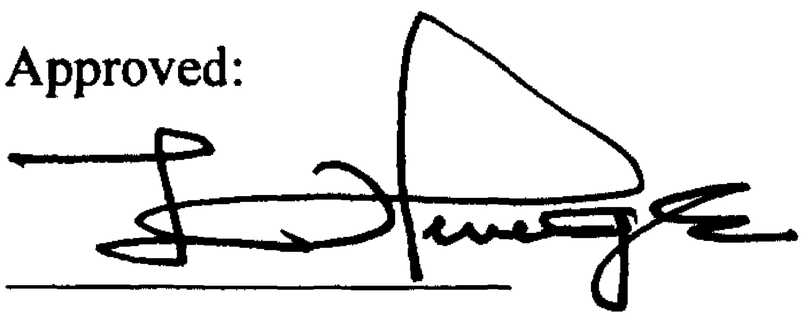
Approved:



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JUNE 2010

CERTIFICATION OF ORIGINALITY

This to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Mohd Asfirdaus Bin Asri

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Firstly, I would like to express my highly gratitude to The Almighty, for giving me the ability and opportunity to conduct this project, through the tough and challenging moment that I have experienced during the event of carrying out several tasks.

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ABSTRACT

Deep beams are very common construction component, which are often used in civil engineering to carry loads for a big space. Transfer beam is used to distribute load from above to the large column beneath it. This study is to design a transfer beam which has a long span of 80 meters. Also to determine suitable formwork design, scaffolding arrangements and construction methodology. A deep beam with long span like this will tend to deflect or even worse fails, and the mid-span. Analysis has to be conducted to study the behavior of this beam in order to avoid failure and minimize deflection over tolerable limit. This study will covers from design and deep beam analysis, suitable formwork design, scaffolding arrangements and construction methodology. Design Reinforced Concrete, Beam analysis, Formwork design will be use as aid in this study.

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CHAPTER 1 INTRODUCTION

1.1. BACKGROUND OF STUDY

Transfer beam is a large beam placed mostly on the second floor to distribute load from upper floor to large column beneath it. It is usually a beam, design to be deep in order to withstand high point load at certain point and distribute it to the column.

This study is focusing on long span simply supported deep beam. Long span deep beam can suit architect's demand on certain structure. Now it has become a common architect design to have buildings with fewer columns to gain additional spaces for interior designing purposes and other things.

This project touches every aspect of constructing a transfer beam. From design stage, construction stage and its completion. A long simply supported transfer beam is not a common practice in Malaysia, making this project valuable for future usage.

1.2. PROBLEM STATEMENT

A long simply supported transfer beam will have very deep depth. This beam will tend to deflect at it mid-span during the construction or even after the construction complete. In order to minimize deflection of this long deep beam or even worse, fails, this study is conducted to design an 80 meters span deep beam, determine suitable formwork design, scaffolding arrangements and construction method.

At design stage, appropriate reinforcement is needed so that its deflection can be minimized within tolerable limit. Even if the beam design shows no sign to deflect exceeding acceptable limit, it somehow can deflect during construction, which makes formwork design and scaffolding arrangements crucial in this project.

Besides that, making it a reality is also an important part in this project. Inappropriate construction practice may results in undesirable effects.

1.3. OBJECTIVES AND SCOPE OF STUDY

1.3.1. OBJECTIVES

The objectives of this study are as below:

- Design deep beam with 80 meters span
- Determine suitable formwork design
- Determine scaffolding arrangements to minimize beam deflection
- Determine suitable construction method

1.3.2. SCOPE OF STUDY

This study will cover deep beam analysis and design, the methods use. Find out suitable formwork design, scaffolding arrangements and construction method for the designed deep beam.

i. Long transfer beam behavior using suitable method.
ii. Scaffolding arrangement to minimize pre-mature deflection.
iii. Formwork design to avoid undesirable effect on the beam shape.
iv. Construction method such as concrete placement, strength and removal of formwork to cater the transfer beam.

CHAPTER 2 LITERATURE REVIEW AND THEORY

2.1. SIZE EFFECT IN RC DEEP BEAM

According to K.-H.Tan [1], beam width is shown to have negligible influence on shear strength for slender deep beam with h/b ratio up to 12.5 but it does have limited effect on crack development. Larger beams show greater propagation rate of flexural cracks.

However, at the ultimate state, arch action rather than flexure dominates the deep beam behavior. Thus, size effect in flexure has little effect on shear strength. The most important thing is, the factors that influence ultimate strength of a compression member govern the size effect, i.e. strut geometry and boundary condition.

There is no substantial effect is seen in the propagation rate of diagonal cracks among beams of different sizes, indicating insignificant size effect. By properly configuring the dimensions of loading and support plates, size effect in ultimate shear strength can be significantly mitigated.

2.2. ANALYSIS

Analysis on the beam has been done to determine load, shear and bending moment of the beam. These are the factors which will affect the beam. The beam has to be design to capacitate this factors otherwise it will fail. In order to design the beam, these factors will be determined to avoid under-design or over-design problems. After analyzing the beam behavior, the suitable formwork and scaffolding arrangement will be design.

2.3. LOAD

Structural loads are forces applied to a component of a structure or to the structure as a unit. In, structural design assumed loads are specified in national and local design codes for types of structures, geographic locations, and usage. In addition to the load

magnitude, its frequency of occurrence, distribution, and nature (static or dynamic) are important factors in design. Loads cause stresses, deformations and displacements in structures. Assessment of their effects is carried out by the methods of structural analysis. Excess load or overloading may cause structural failure, and hence such possibility should be either considered in the design or strictly controlled.

Structural loads consist of two things in this research, which are dead loads and live loads.

DEAD LOAD

The dead load is the weight of the structure acting with gravity on the foundations below. Loads which acting on the beam has been determine. Dead loads acting on the beam contributed from the self weight of the beam, wall loading and slab loading.

BEAM

As for the self weight of the beam, the following equation has been used:

$$G_{kb} = d\ x\ b\ x\ unit\ weight\ of\ conrete$$

WALL

For wall loading, the calculation is as follows:

$$G_{kw} = d\ x\ b\ x\ unit\ weight\ of\ conrete$$

SLAB

For slab loading, the following equation has been used:

$$G_{ks} = dead\ load\ x\ {}^{L_x}/_{2}$$

$$Dead\ load = Slab\ thickness\ x\ unit\ weight\ of\ concrete + finishes$$

TOTAL DEAD LOAD

The total dead load is sum of all the dead loads which is:

$$Total\ Dead\ Load, G_K = Beam\ Load + Wall\ Load + Slab\ Load$$

LIVE LOAD

Live loads, or imposed loads, are temporary, of short duration, or moving. The live loads are calculated as follows:

$$Live\ load, Q_K = {}^{L_x}/_{2}\ x\ live\ load\ value$$

TOTAL LOAD

Total load is the sum of the dead loads and live loads acting on the beam. Total load is calculated using the following equation:

$$Total\ load, W_u = 1.4G_k + 1.6Q_y$$

2.4. SHEAR STRESS

Shear stress is defined as a stress which applied parallel or tangential to a face of material, as opposed of normal stress which is applied perpendicularly. For beam, it is defined as the internal shear stress of a beam which is caused by shear force applied to the beam.

In order to determine the shear stress applied on the beam the following equation has been used:

$$V = \frac{w_u l}{2}$$

$w_u = total\ load$

$l = beam\ span$

2.5. BENDING MOMENT

A bending moment exists in a structural element when a moment is applied to the element so that the element bends. Moments and torques are measured as a force multiplied by a distance so they have as unit newton-metres (N·m) , or foot-pound force (ft·lbf). The concept of bending moment is very important in civil engineering.

When a bending moment exists in a structural element it induces tensile stresses and compressive stresses in the element. Tensile stresses and compressive stresses increase proportionally with bending moment, but are also dependent on the second moment of inertia of the cross-section of the structural element. Failure in bending will occur when the bending moment is sufficient to induce tensile stresses greater than the yield stress of the material. It is possible that failure of a structural element in shear may occur before failure in bending; however the mechanics of failure in shear and in bending are different.

The bending moment at a section through a structural element may be defined as "the sum of the moments about that section of all external forces acting to one side of that section". The forces and moments on either side of the section must be equal in order to counteract each other and maintain a state of equilibrium so the same bending moment will result from summing the moments, regardless of which side of the section is selected.

Critical values within the beam are most commonly annotated using a bending moment diagram, where negative moments are plotted to scale above a horizontal line and positive below. Bending moment varies linearly over unloaded sections and parabolic manner over uniformly loaded sections.

Bending moment is calculated using this equation:

$$M = \frac{w_u l^2}{8}$$

2.6. DESIGN

Analysis has been done in order to determine the shear and bending moment. From the data obtain in the analysis; the beam has to be design to be able to withstand the force that will be applied on it. Over-design will result in brittle manner when the beam fails, which is not safe as there is no warning. Unlike under-design condition, where before the beam fails, it behaves in a ductile manner. It will deflect first and this is considered as fails in a safe manner as it shows the sign of failure.

2.7. BENDING MOMENT DESIGN

COMPRESSION REINFORCEMENT

$$d' = cover + \frac{\emptyset}{2}$$

$$z = d(0.5 + \sqrt{(0.25 - {K'}/{0.9})})$$

$$A_s{}' = \frac{M - M_u}{0.95 f_y (d - d')}$$

$$Number\ of\ bars = \frac{A_s{}'}{(\frac{\pi}{4})d^2}$$

TENSION REINFORCEMENT

$$A_s = \frac{M_u}{0.87 f_y z} + A_s{}'$$

$$Number\ of\ bars = \frac{A_s}{(\frac{\pi}{4})d^2}$$

2.8. SHEAR DESIGN

$$v = \frac{V}{bd}$$

$$\frac{100A_s}{bd}$$

$$v_{c25} = 0.79(\frac{100A_s}{bd})^{1/3}(\frac{400}{d})^{1/4}\frac{1}{\gamma_m}$$

$$v_c = (\frac{f_{cu}}{25})^{1/3}(v_{25c})$$

$$S_{vmax} = 0.75\ x\ d$$

$$0.5v_c < v_c + 0.4 < v$$

$$A_{sv} = \frac{0.4\ x\ b\ x\ S_v}{0.95f_y}$$

$$S_v = \frac{0.95f_{yv}A_{sv}}{b(v - v_v)}$$

$$legged = \frac{A_{sv}}{\frac{\pi}{4}xd^2}$$

2.9. DEFLECTION

Deflection is a term that is used to describe the degree to which a structural element is displaced under a load. The deflection of a member under a load is directly related to the slope of the deflected shape of the member under that load and can be calculated by

integrating the function that mathematically describes the slope of the member under that load.

$$Span/_{Effective\ Depth} = 20\ (From\ Table\ 3.9\ BS\ 8110 - 1\ 1997)$$

2.10. FORMWORK

Formwork is temporary structures that act as mould for the beam. The term "Temporary Structures" may not fully imply as temporary since some form, ties and accessories are being used for multiple times. Unlike conventional structure, the formwork disassembly characteristics are severely restricted by concrete bond, rigidity and shrinkage. Lumber was once the predominant form materials, but as for today, several materials had been used as formwork such as plywood, metal, plastics and other materials.

Besides acting as mould, formworks also act as a support for its own weight, freshly placed concrete and construction's live loads. Formwork has three objectives to be achieve which are quality, safety and economy. Quality of a formwork consists of strength, rigidity, position and dimension of the formwork. As for safety, we are looking to keep it safe for the worker and the concrete structures. While trying to comply with these criteria, designing formworks should be cost effective. In order to achieve these targets, engineers, architects and the contractors should have good cooperation and teamwork.

Formwork plays a crucial part in concrete structure. The alignment, size and shape are depending on the accuracy of formworks. Formworks should be sufficiently rigid under construction load to maintain the designed shape of the concrete. It should stable and strong enough to keep structure aligned. The formwork shouldn't be removed until the concrete is strong enough to avoid the concrete losing its shape.

Failure of formwork can cause unwanted accident and may cost lives. There are several main factors which cause formwork to fail. They are:

1. Improper stripping and shore removal
    a. Premature stripping of form, premature removal of shores and careless practice in re-shoring
2. Inadequate bracing
    a. Inadequate cross bracing and horizontal bracing of shores
    b. Induce lateral force components or induce displacement of supporting members
3. Vibration
    a. Vibration caused by passing traffic
    b. Vibration caused by movement of workers and equipment on the formwork
    c. Vibrating concrete to consolidate it
4. Unstable soil under mudsills
    a. Moisture and heat from concreting operations may thaw the soil and allow settlements that overloads or shift the formworks
    b. Site drainage should be sufficient to prevent a washout of soil supporting the mudsills
5. Inadequate control of concrete placement
    a. The temperature and rate of vertical placement of concrete influencing the development of lateral pressures that act on the formwork.
    b. Failure to regulate properly the rate and order of placing concrete on horizontal surfaces or curved roofs may produce unbalanced loadings and consequent failures of the formwork.
6. Lack of attention to formwork detail
    a. Small differences in assembly details may cause local weakness or overstress

Above all, safety becomes the number one concern. Recommendations from OSHA (Occupational Safety and Health Administration) and local codes should be followed.

According to M. Nemati [8], horizontal concrete formwork, such as formwork for slabs, consist of sheathing, normally made of plywood, which rests on joists, and joists are supported by stringers, and stringers are supported on shores which carry the weight of the entire system. He also stated several vertical loads which acting on the formwork, they are:

- the weight of reinforced concrete;
- the weight of forms themselves (dead load); and
- the live loads imposed during the construction process (material storage, personnel and equipment).

ACI Committee 347 recommends that both vertical supports and horizontal framing components of formwork should be designed for a minimum live load of 50 psf of horizontal projection to provide for weight of personnel, runways, screeds (equipment used for precise strike-off and consolidation of concrete surfaces) and other equipment. When motorized carts are used, the minimum should be 75 psf. Regardless of slab thickness, the minimum design value for combined dead and live loads should be 100 psf, or 125 psf if motorized carts are used.

When slab form members are continuous over several supporting shores, dumping concrete on one span of the form member may cause uplift of the form in other spans. Forms must be designed to hold together under such conditions.

2.11. SCAFFOLDING

Scaffolding is a temporary structure used to support people and material in the construction or repair of buildings and other large structures. It is usually a modular system of metal pipes, although it can be made out of other materials. Bamboo is still used in some Asian countries like China.

The key elements of a scaffold are standards, ledgers and transoms. The standards, also called uprights, are the vertical tubes that transfer the entire mass of the structure to the

ground where they rest on a square base plate to spread the load. The base plate has a shank in its centre to hold the tube and is sometimes pinned to a sole board. Ledgers are horizontal tubes which connect between the standards. Transoms rest upon the ledgers at right angles. Main transoms are placed next to the standards, they hold the standards in place and provide support for boards; intermediate transoms are those placed between the main transoms to provide extra support for boards. Since scaffolding is a physical structure, it is possible to go in and come out of scaffolding.

As well as the tubes at right angles there are cross braces to increase rigidity, these are placed diagonally from ledger to ledger, next to the standards to which they are fitted. If the braces are fitted to the ledgers they are called ledger braces. To limit sway a facade brace is fitted to the face of the scaffold every 30 metres or so at an angle of 35°-55° running right from the base to the top of the scaffold and fixed at every level.

Of the couplers, right-angle couplers join ledgers or transoms to standards, putlog or single couplers join board bearing transoms to ledgers - Non-board bearing transoms should be fixed using a right-angle coupler. Swivel couplers are to connect tubes at any other angle. The actual joints are staggered to avoid occurring at the same level in neighbouring standards.

The spacing of the basic elements in the scaffold are fairly standard. For a general purpose scaffold the maximum bay length is 2.1 m, for heavier work the bay size is reduced to 2 or even 1.8 m while for inspection a bay width of up to 2.7 m is allowed.

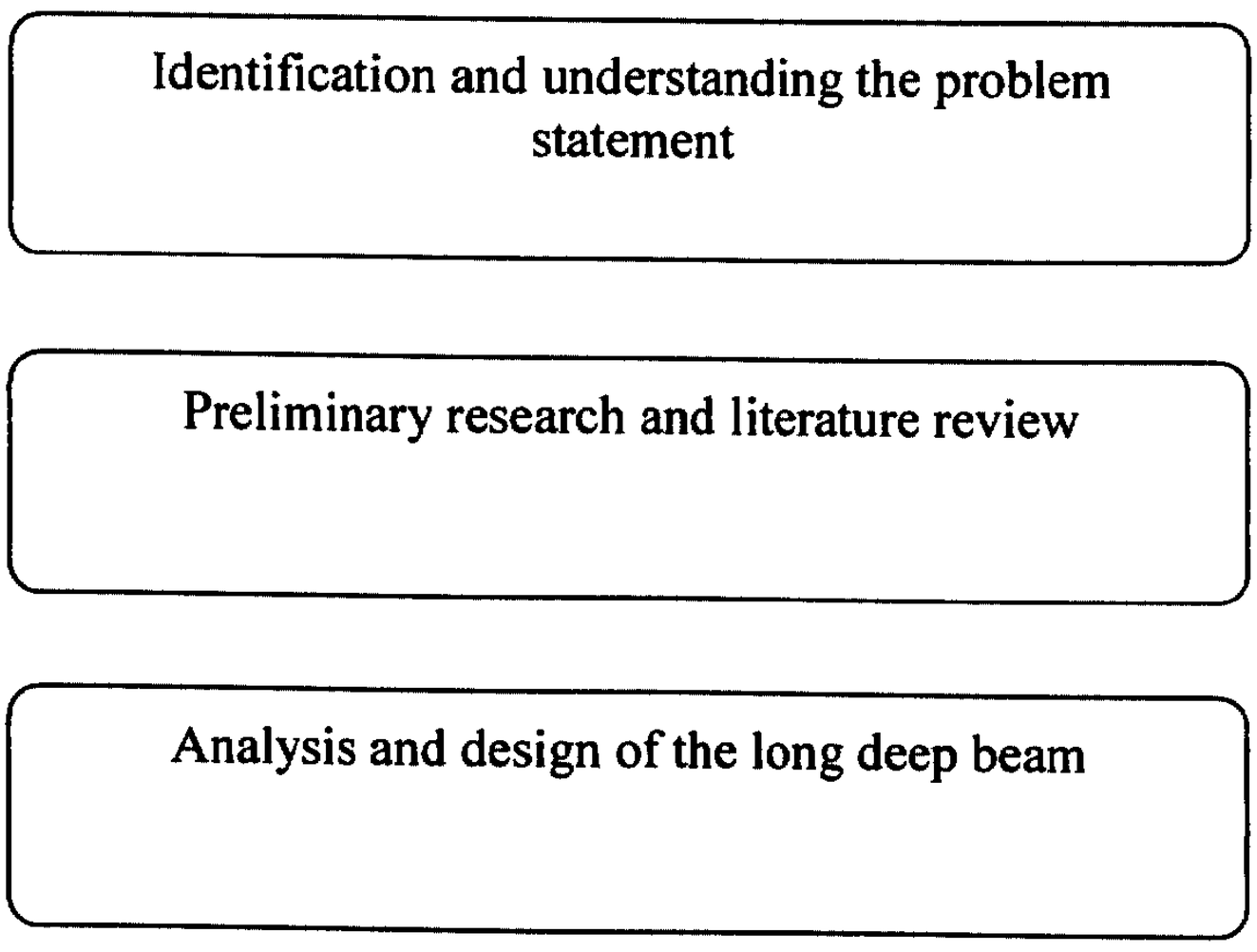
The scaffolding width is determined by the width of the boards, the minimum width allowed is 600 mm but a more typical four-board scaffold would be 870 mm wide from standard to standard. More heavy duty scaffolding can require 5, 6 or even up to 8 boards width. Often an inside board is added to reduce the gap between the inner standard and the structure.

The lift height, the spacing between ledgers, is 2 m, although the base lift can be up to 2.7 m. The diagram above also shows a kicker lift, which is just 150 mm or so above the ground.

Transom spacing is determined by the thickness of the boards supported, 38 mm boards require a transom spacing of no more than 1.2 m while a 50 mm board can stand a transom spacing of 2.6 m and 63 mm boards can have a maximum span of 3.25 m. The minimum overhang for all boards is 50 mm and the maximum overhang is no more than 4x the thickness of the board.

CHAPTER 3 METHODOLOGY AND PROJECT WORK

3.1. PROCEDURE IDENTIFICATION



3.2. BEAM ANALYSIS AND DESIGN

The beam will be analyzed to find the suitable design requirements. Using Beam Theory, load, shear stress, bending moment and deflection will be determined. Based on BS CODE 8110-1:1997, analysis and design will be conducted.

Load acting on the beam will be analyzed. The live load, dead load and the total load which acting on the beam will be analyze to determine the suitable design for the beam. Shear acting on it will also be analyzed to provide sufficient shear reinforcement for the beam. Links used will be determined. As for the bending moment acting on it, it will be determined using the equation from Beam Theory. Thus, enabling the determination of reinforcements bars needed for the beam. The beam will also be checked for deflection to make sure that it would not exceed the tolerable limit.

After all the analysis and design of the beam have been completed, then the next stage of determining the suitable formwork will be executed.

3.3. SUPPLIER CATALOGUE FOR FORMWORK AND SCAFFOLDING DESIGN

In order to design formwork and scaffolding, formwork and scaffolding specifications need to be obtained. Finding supplier who can provide catalogue or any information and specifications which can be use to analyze and design the formwork and scaffolding.

Supplier catalogue will provide the technical specifications of the formwork and scaffolding. Using the technical data of the formwork, the suitable formwork can be determined. Based on the analysis done on the forces that acting on the beam, the suitable formwork's plywood and wood will be chosen.

As for the scaffolding, the total load of dead load, live load and construction load determined will be used to select the suitable scaffolding to cater the transfer beam.

3.4. SOFTWARE

MICROSOFT EXCEL is used to develop spreadsheet for designing purposes such as beam design, formwork design and scaffolding arrangements. EXCEL provides features that are useful in simplifying the analysis and the design works. Equation and formulae needs can be set to use. It can calculate equations automatically making it reliable for design purposes. Errors in calculation can also be avoided as it used the computerized synchronization of data which will avoided unparallel changes in the data.

Known data will be put in the spreadsheet. Corresponding equation will be set and linked with the related data to get the data needed such as loadings. Loads, shear and moment acting the beam can be determined thus enabling the design of the beam.

As for designing of the beam purposes, the same method will be used to get reinforcements needed for the transfer beam. It will provide the simplicity of work and save time in designing the beam.

As for formwork and scaffolding arrangements, same method will be used to get acting loads. From the calculated data, the formwork and scaffolding arrangements can be determined.

CHAPTER 4 RESULTS AND DISCUSSIONS

4.1. BEAM DESIGN

From the analysis that had been conducted, an 80m long transfer beam has been design. It is under a higher bending moment acting on it compared to its ultimate bending moment, which are $259094kN \cdot m$ and $52280kN \cdot m$ respectively. Thus, doubly reinforcement is needed. From the calculations, the compression reinforcement is 130T40 and the tension reinforcement is 176T40. Higher area of steel needed in the tension reinforcement is to backup the weakness lies in reinforced concrete structures which is tensile stress. As for the shear reinforcement, a 16 legged T12 @ 218mm is needed for both tension reinforcements and compression reinforcements.

Then, the beam design had been checked for deflection. According to BS CODE 8110-1:1997, the beam would not excessively deflect if span/effective depth ratio is not greater than the appropriate ratio in table 3.9 from BS CODE 8110-1:1997. As for this project, the beam is a simply supported beam whose span/effective ratio of 20. However, tension and compression reinforcements do affect the beam deflection. After calculating the tension reinforcement and compression reinforcement modification factor, then multiplied with ratio in table 3.9 from BS CODE 8110-1:1997, a ratio of 24.528 is calculated. The beam span/effective ratio is 27, which exceeded the appropriate ratio. Further investigation is needed to calculate its deflection to get an accurate result. However, the beam depth can be changed to avoid exceeding ratio. Minimum effective depth of 3262mm should suffice so that it will not exceed appropriate ratio.

4.2.FORMWORK DESIGN & SCAFFOLDING ARRANGEMENT

Using conventional formwork system, the formwork of this transfer beam has been designed. From JASHIN Engineering (M) Sdn. Bhd catalogue technical data for plywood and timber formwork and scaffolding from appendix, the formwork and scaffolding arrangement has been determined.

From the calculation done, the timber joist size chose for supporting the beam is hardwood sawn timber with 200mmx100mm dimension and six rafter spacing at 140mm.Based on the Deflection vs Load intensity table of the plywood (refer appendix), 12mm thick waterproof plywood to be supported at 140mm c/c or less, the deflection shall be less than 1.0mm.

As for the scaffolding arrangements, 50kN frame has been choose for safe working load which able to withstand the beam dead load and other imposed load such as construction working load. This is to ensure a safe working condition as the most important thing is safety at the construction site.

4.3. CONSTRUCTION METHODOLOGY

Construction methodology is the method used to construct the beam. After analyzing the design of the beam, certain construction methods have been developed. The concrete placing technique, compacting, curing and the formwork removal methods will be discussed.

4.3.1. CONCRETE PLACING AND COMPACTING

Since the beam is a long beam, it cannot be poured in one continuous operation. It should be poured in multiple operations and joined using construction joint. As for this project, the concrete should be poured in sequence. Sequence should be in vertical and horizontal layers.

The horizontal layers will be poured in a continuous operation. The concrete should be pour not more than 24 inch thick per layer. The successive layers need to be poured before preceding layers has taken its initial set. Initial set would take about 45 minutes to an hour. Too much time taken for placement between each layer will result in cold joint which is weak.

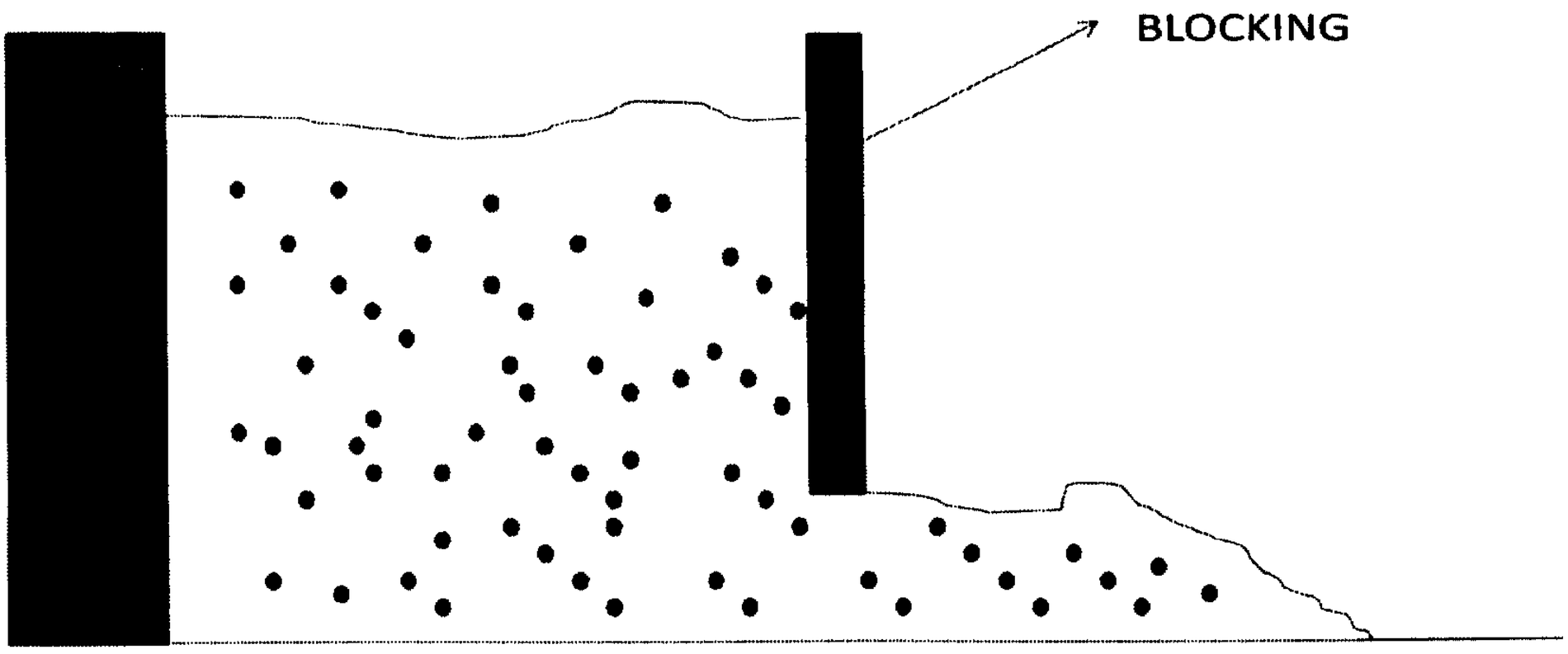


Figure 1 Concrete placement with blocking

Each vertical layer should be block with formwork which has an opening at the bottom. This is to allow concrete to get to the other side of the blocking in order to provide a joint between each layer of the concrete. Construction joint will be place at the concrete connector at the other side. To make the construction joint, a raised keyway or keyways in the section to be poured later need to be formed. After the first section hardened, the surface should be swept clean and kept wet. A bonding epoxy can be applied to the exposed area before resume pouring. The construction joint will be a vertical joint to resist shear and other forces.

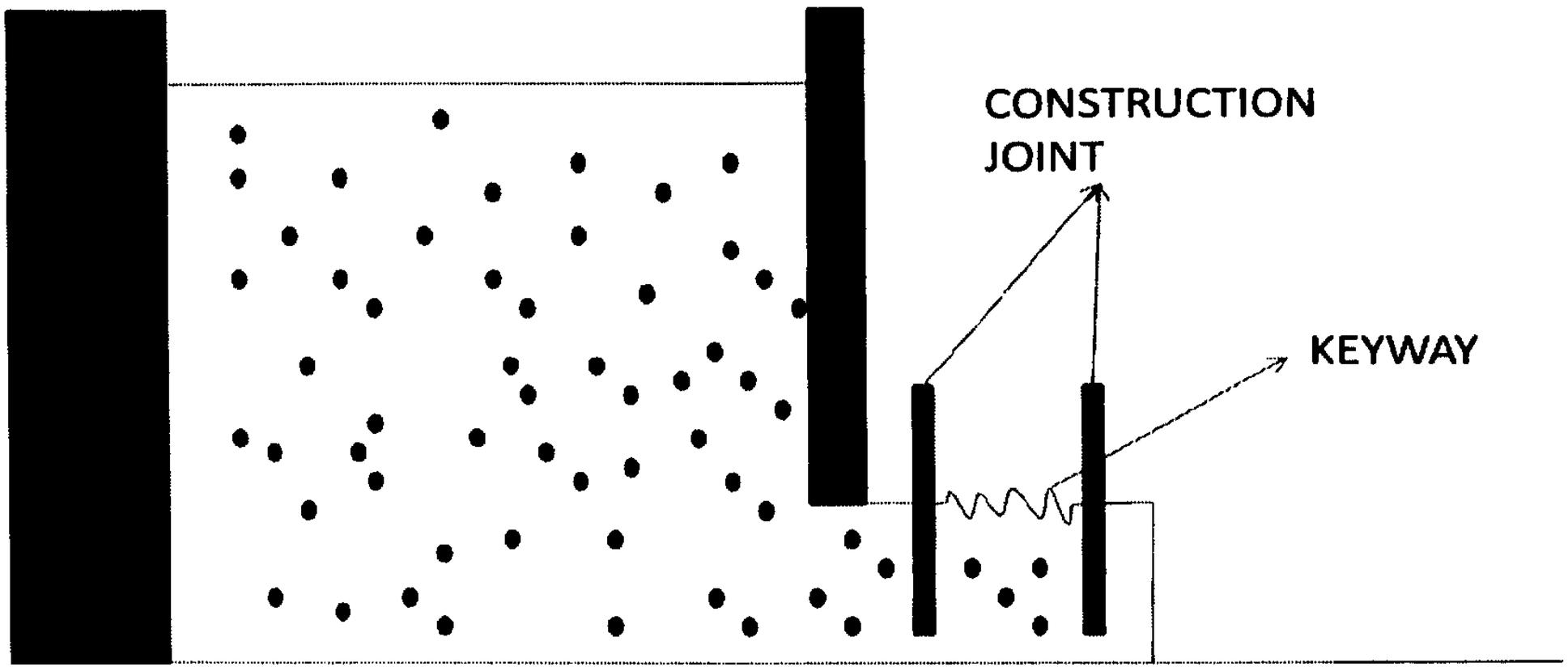


Figure 2 Construction joint and keyway

When placing and compacting the concrete, several factor need to be paid attention to. According to BS CODE 8110-1-1997, they are:

a. Placing should be done with care to avoid displacing the reinforcement, formwork and damages to the formwork.
b. Moving the concrete across the surface of open textured formwork should be avoided to avoid localized honey-combing and inadequate bonding between the concrete and reinforcement.
c. Concrete should not be placed under flowing water and should be placed in position my tremies or by pipeline from mixer.
d. Concrete should be compacted by vibration using vibrator. Vibration should be applied to remove air in concrete to avoid segregation. However, over-vibration should be avoided as it promote weak surface layer.
e. Extra care is required to ensure full compaction as it cannot be checked when the formwork is removed.

4.3.2. CURING

Once the concrete is in place, the concrete is allowed to cure a certain amount of time to achieve the full strength. During the curing period, the concrete is not to be placed under stress. The curing period of the concrete is 96 hours after the initial set. Using protective covering curing method, it requires covering the surfaces to be cured with canvas, straw, burlap, sand, or other approved material and keeping the concrete wet with water throughout the curing period. The water prevents the concrete from drying out too quickly.

4.3.3. FORMWORK REMOVAL

Most of formwork systems cost increases the longer the forms remains in place, thus the timing of formwork removal is as very important subject. Removing the formwork as soon as possible without affecting the structure safety and damages will be an efficient use of the formwork.

In order to remove formwork early, the concrete strength needs to be determined. Formworks can be removed when the concrete strength had reached 10 N/mm2 or twice the stress to which it will be subjected, whichever is greater.

Concrete strength can be determined using test cube with curing under the same element as the beam. Thus formwork removal time can be determined with test cube. Test cube strength will be recorded. Then plot it in Strength vs. Time graph. Note the time it takes for the concrete to reach 10 N/mm2. That is the time when the formwork is safe for removal.

Formwork removal is based on concrete strength. Therefore factors that affecting concrete strength will also affect the removal time. Main factor that is affecting concrete strength development is concrete temperature. Thus, in order to develop a removal time concrete temperature needs to be put into consideration.

CHAPTER 5 CONCLUSION AND RECOMMENDATION

5.1. BEAM

The beam design needed to pay attention on the tensile strength as the beam is very long. Reinforcement on the bottom is crucial as the beam will tend to deflect. It will put more stress on the bottom part compare to the top part. Beam detailing needs to be stressed on the tensile strength as concrete is known for its high compressive strength but with lower tensile strength.

5.2. CONCRETE PLACEMENT TECHNIQUES

Concrete placement technique is important in constructing this beam as the size and its dimension is large. Without proper techniques, it will result in failure and deflection. It needs to be poured in sequence vertically and horizontally with construction joints to make sure it will have strength it needs and to avoid unwanted incident.

5.3. FORMWORK REMOVAL TIME

Time to remove the formwork is one the important part in constructing this beam as early removal will do damages to the beam and also caused it to deflect if it does not gain the minimum strength it needs to support its own weight and other imposed loads.

5.4. CONCLUSION

The proposed project title can help designing and constructing long deep beam. This will give chance to architects to dream more on their building design as it will enable more usable spaces in buildings for other use. Column will take lesser space as the number of column can be reduced significantly. The objective of the project can be fulfilled successfully through the hard work and good engineering judgment.

5.5. RECOMMENDATION

This study should be continued in future especially in formwork removal factors such as concrete maturity. The factors that affecting the formwork removal time is not just speeds up construction time but also save cost and increase safety.

CHAPTER 6 ECONOMIC BENEFITS

This project focus on the transfer beam design and its construction methodology in which always depends on the economic factor as well as safety. Designing has always aimed to design something that is safe and economical. As for construction methodology, safety and economy has always been the important factor which can't be neglect because it will cost money and the most important thing, human lives if it is not done correctly.

Transfer beam cost a lot compared to normal beam due to its size. It requires more reinforcement and more concrete to fit its role of distributing the load from upper structure to the lower part. However, it does not only withstanding the upper load, but also its own dead load. Thus, designing plays an important role so that the beam will be able to hold all the loads acting on it. Failure to design a transfer beam that can withstand the acting load will result in undesirable effects, which will lead to bending exceeding tolerable limit or worse, failure.

Besides that, the formwork design is also crucial as it will act as a support for the beam during construction. It has to be able to withstand the beam load as well as construction's loads. Designing a suitable formwork will play an important role in a project as it will avoid excessive deflection because the beam did not gain its full strength yet to be able to withstand loads acting on it.

A suitable construction methodology will avoid unwanted incidents. Concrete pouring and formwork removal time are crucial as it will affect the safety as well as cost. This transfer beam is large long beam which cannot be poured in one go. It needs to be poured simultaneously. As for the formwork removal time, the faster the time needs to remove the formwork, the better as it will reduce the operating cost. However, to remove the formwork earlier than it supposed to be will result in beam deflection which can exceed the tolerable limit.

In the design and analysis, optimizing reinforcements will help achieving the best value for money which is safe and cost-saving. In return, it will give economic benefits that can provide safety with reasonable cost. As for formwork design, determining the suitable formwork and scaffolding will help reduce the cost and increase safety. If the formwork provided does not deliver its role of supporting the transfer beam, it may cost more which might involve not just money, but human lives. In the other hand, the construction method will help reduce cost and at the same time comply with safety. A suitable concrete pouring technique can help avoiding cracks in concrete and provide the strength the beam needs, which will help reduce cost of repairing. From the economic point of view, it reduces the overall cost since the repairing costs have been eliminated. As for formwork removal time, to determine the best time to remove the formwork will help reduce construction cost as it will avoid optimized the use of formwork. The longer time the formwork stays in place, the higher the cost will be. Thus, eliminating unwanted days of formwork staying in place will reduce unnecessary costs while providing the safety it needs.

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APPENDICES

CALCULATIONS

BEAM ANALYSIS

Dead load

Beam Sizing

$d = 3000\ mm = 3\ m$

$b = 850\ mm = 0.85\ m$

$unit\ weight\ of\ concrete = 24\ {}^{kN}/_{m^3}$

Therefore,

$G_{kb} = 3\ x\ 0.85\ x\ 24$

$G_{kb} = 61.2kN$

Wall Sizing

$d = 2200\ mm = 2.2\ m$

$b = 850\ mm = 0.85\ m$

$unit\ weight\ of\ concrete = 18\ {}^{kN}/_{m^3}$

Therefore,

$G_{kw} = 2.2\ x\ 0.85\ x\ 24$

$G_{kw} = 7.92kN$

Slab Details

$Slab\ thickness = 150\ mm = 0.15\ m$

$L_x = 30\ m$

$L_y = 80\ m$

$finishes = 1.5\ {}^{kN}/_{m^3}$

Therefore,

$$Dead\ load = 0.15\ x\ 24 + 1.5$$

$$Dead\ load = 5.1$$

$$G_{ks} = 5.1\ x\ {}^{30}/_{2}$$

$$G_{ks} = 76.5kN$$

Therefore,

$$Total\ Dead\ Load, G_K = 61.2 + 7.92 + 76.5$$

$$Total\ Dead\ Load, G_K = 145.62kN$$

Live load value has been taken from BS 6399: Part 1: 1996

$$Live\ load\ value = 5.0$$

Therefore,

$$Live\ load, Q_K = {}^{30}/_{2}\ x\ 5$$

$$Live\ load, Q_K = 75kN$$

Therefore,

$$Total\ load, W_u = 1.4(76.5) + 1.6(75)$$

$$Total\ load, W_u = 323.9kN$$

SHEAR STRESS

$$V = \frac{323.9(80)}{2}$$

$$V = 12954.7kN$$

BENDING MOMENT

$$M = \frac{323.9(80)^2}{8}$$

$$M = 259094kN \cdot m$$

BEAM DESIGN

BENDING MOMENT

Section Details

b	cover	d	f_{cu}	f_y
850	40	2960	45	460

ULTIMATE DESIGN MOMENT

$$M_u = 0.156\ x\ f_{cu}\ x\ b\ x\ d^2$$

Therefore,

$M_u = 0.156\ x\ 45\ x\ 850\ x\ 2960^2$

$M_u = 52280kN \cdot m$

$52280 < 259094$

$M_u < M$

Thus, it is a Doubly Reinforcement

DOUBLY REINFORCEMENT

COMPRESSION REINFORCEMENT

$$d' = cover + \frac{\emptyset}{2}$$

Assuming the compression steel to be 40 mm in diameter,

$$d' = 40 + \frac{40}{2}$$

$d' = 60mm$

$$z = d(0.5 + \sqrt{(0.25 - {K'}/{0.9})})$$

$K' = 0.156$

Therefore,

$$z = 2960(0.5 + \sqrt{(0.25 - {0.156}/{0.9})})$$

$z = 2299.6mm$

$$x = \frac{(d - z)}{0.45}$$

Therefore,

$$x = \frac{(2960 - 2299.6)}{0.45}$$

$x = 1467.59$

$$\frac{d'}{x} = \frac{60}{1467.59}$$

$$\frac{d'}{x} = 0.04088 < 0.43$$

Thus compression steel has yielded

$$A_s' = \frac{M - M_u}{0.95 f_y (d - d')}$$

Therefore,

$$A_s{}' = \frac{(259094 - 52280)10^6}{0.95(460)(2960 - 60)}$$

$$A_s{}' = 163192.6mm^2$$

Assume diameter to be 40 mm

$$Number\ of\ bars = \frac{A_s{}'}{(\frac{\pi}{4})d^2}$$

Therefore,

$$Number\ of\ bars = \frac{163192.6}{(\frac{\pi}{4})40^2}$$

$$Number\ of\ bars = 129.86 \approx 130$$

Thus, provide **130T40**

TENSION REINFORCEMENT

$$A_s = \frac{M_u}{0.87 f_y z} + A_s{}'$$

Therefore,

$$A_s = \frac{52280}{0.87(460)(2299.6)} + 163192.6$$

$$A_s = 220001mm^2$$

Assume diameter to be 40 mm

$$Number\ of\ bars = \frac{A_s}{(\frac{\pi}{4})d^2}$$

Therefore,

$$Number\ of\ bars = \frac{220001}{(\frac{\pi}{4})40^2}$$

$$Number\ of\ bars = 175.07 \approx 176$$

Thus, provide **176T40**

SHEAR

TENSION SHEAR REINFORCEMENT

Shear Stress

$$v = \frac{V}{bd}$$

Therefore,

$$v = \frac{12954.7\ x\ 1000}{850(2960)}$$

$$v = 5.15\ Mpa$$

$$\frac{100A_s}{bd}$$

Therefore,

$$= \frac{100(221168.12)}{(850)(2960)}$$

$$= 8.79$$

For $f_{cu} = 25$

$$v_{c25} = 0.79(\frac{100A_s}{bd})^{1/3}(\frac{400}{d})^{1/4}\frac{1}{\gamma_m}$$

Therefore,

$$v_{c25} = 0.79(8.79)^{1/3}(\frac{400}{2960})^{1/4}\frac{1}{1.25}$$

Since max value for $v_c = 0.91$

$v_{25c} = 0.91008 = 0.91$

For $f_{cu} = 45$

$$v_c = (\frac{f_{cu}}{25})^{1/3}(v_{25c})$$

Therefore,

$v_c = (\frac{45}{25})^{1/3}(0.91)$

$v_c = 1.11$

$0.5v_c = 0.55$

$0.4 + v_c = 1.51$

MaximumS_v,

$$S_{vmax} = 0.75\ x\ d$$

Therefore,

$S_{vmax} = 0.75\ x\ 2960$

$S_{vmax} = 2220mm$

Take $Actual\ S_V = 2200mm$

$$0.5v_c < v_c + 0.4 < v$$

Thus,

$$A_{sv} = \frac{0.4\ x\ b\ x\ S_v}{0.95f_y}$$

Therefore,

$A_{sv} = \frac{0.4\ x\ 850\ x\ 2200}{0.95(460)}$

$A_{sv} = 1711.67 \approx 1712mm^2$

$$S_v = \frac{0.95f_{yv}A_{sv}}{b(v - v_v)}$$

Therefore,

$S_v = \frac{0.95(460)(1712)}{850(5.15 - 1.11)}$

$S_v = 217.86 \approx 218mm$

Assume the diameter to be 12 mm

$$legged = \frac{A_{sv}}{\frac{\pi}{4}xd^2}$$

Therefore,

$$legged = \frac{1712}{\frac{\pi}{4}x12^2}$$

$$legged = 15.137 \approx 16$$

Thus it is 16 Legged T12 @ 218 mm

COMPRESSION SHEAR REINFORCEMENT

Shear Stress

$$v = \frac{V}{bd}$$

Therefore,

$$v = \frac{12954.7\ x\ 1000}{850(2960)}$$

$$v = 5.15\ Mpa$$

$$\frac{100A_s}{bd}$$

Therefore,

$$= \frac{100(163362.82)}{(850)(2960)}$$

$$= 6.49$$

For $f_{cu} = 25$

$$v_{c25} = 0.79(\frac{100A_s}{bd})^{1}/_{3}(\frac{400}{d})^{1}/_{4}\frac{1}{\gamma_m}$$

Therefore,

$$v_{c25} = 0.79(6.49)^{1}/_{3}(\frac{400}{2960})^{1}/_{4}\frac{1}{1.25}$$

Since max value for $v_c = 0.91$

$v_{25c} = 0.91008 = 0.91$

Value of $v_c = 0.91$ for Compression Shear Reinforcement is the same as Tension Shear Reinforcement, therefore it will give the same reinforcement design.

Thus,

$$A_{sv} = \frac{0.4\ x\ b\ x\ S_v}{0.95 f_y}$$

Therefore,

$$A_{sv} = \frac{0.4\ x\ 850\ x\ 2200}{0.95(460)}$$

$A_{sv} = 1711.67 \approx 1712mm^2$

$$S_v = \frac{0.95 f_{yv} A_{sv}}{b(v - v_v)}$$

Therefore,

$$S_v = \frac{0.95(460)(1712)}{850(5.15 - 1.11)}$$

$$S_v = 217.86 \approx 218mm$$

Assume the diameter to be 12 mm

$$legged = \frac{A_{sv}}{\frac{\pi}{4}xd^2}$$

Therefore,

$$legged = \frac{1712}{\frac{\pi}{4}x12^2}$$

$$legged = 15.137 \approx 16$$

Thus it is **16 Legged T12 @ 218 mm**

DEFLECTION

Modification factor for Tension Reinforcement

$$Modification\ Factor = 0.55 + \frac{(477 - f_s)}{120(0.9 + \frac{M}{bd^2})}$$

$$f_s = \frac{2f_y A_{s\,req}}{3A_{s\,prov}}\ x\ \frac{1}{\beta_b}$$

Therefore,

$$f_s = \frac{2(460)(220001)}{3(221168)}\ x\ \frac{1}{1}$$

$$f_s = 305.05$$

Sub f_s into

$$Modification\ Factor = 0.55 + \frac{(477 - f_s)}{120(0.9 + \frac{M}{bd^2})}$$

$$Modification\ Factor = 0.55 + \frac{(477 - 305.05)}{120(0.9 + \frac{52280(10^6)}{850(2960)^2})}$$

$$Modification\ Factor = 0.73$$

Modification factor for Compression Reinforcement

$$\left. 1 + \frac{100A'_{s\,prov}}{bd} \middle/ (3 + \frac{100A'_{s\,prov}}{bd}) \right. \leq 1.5$$

Therefore,

$$Modification\ Factor = \left. 1 + \frac{100(163362.82)}{(850)(2960)} \middle/ (3 + \frac{100(163362.82)}{(850)(2960)}) \right.$$

$$Modification\ Factor = 1.68$$

$$Span/_{Effective\ Depth} x\ MF\ Compression\ x\ MF\ Tension = 20\ x\ 1.68\ x\ 0.73$$

$$= 24.528$$

$$Span/_{Effective\ Depth} Beam = 80000/_{2960}$$

$$Span/_{Effective\ Depth} Beam = 27$$

Worked out analysis and design for beam reinforcement

1. Analysis

					Left side	right side	Left side	right side	Left side	right side	Left side	right side	Left side	right side
	$L_{x,left}$	$L_{x,right}$	$L_{y,left}$	$L_{y,right}$	type		thickness		live load		finishes		dead load	
Supporting Slab	30	0	80	0	one way	#DIV/0!	150	0	5	0	1.5	0	5.1	0

Beam **Simply Supported Uniformly Distributed**

	H/D	b	unit weight	load
Loading				
Beam	3000	850	24	61.2
Wall	2200	200	18	7.92
Dead Load from Slab, kN				76.5
[redacted]				[redacted]
Live Load from Slab, kN				75
[redacted]				[redacted]
Span				80
[redacted]				[redacted]
Shear, V, kN				12954.7

2. Design	b	cover	d	fcu	fy	γ_m
Section detail	850	40	2960	45	460	1.25
[redacted]	52280					
M versus Mu	**Doubly Reinforced Section**					

Doubly Reinforced Section

Compression Reinforcement

d'	60				
z, mm	2299.6				
x	1467.584694				
d'/x	0.040883501	OK			
		dia		Say	
As'	163192.5612	40	129.86	130.00	130H40

Tension Reinforcement

As	220001	40	175.07	176.00	113H40

Tension Shear Design

v, Mpa	5.15		
100As/bd	6.49		
vc for fcu = 25	0.91	0.5vc	vc+0.4
vc for fcu = fcu	1.11	0.55	1.51
Maximum, sv	2220		
Actual Sv	2200		
Asv	1712		
dia	12		
legged	16		

Compression Shear Design

v, Mpa	5.15		
100As/bd	8.79		
vc for fcu =	0.91	0.5vc	vc+0.4
vc for fcu =	1.11	0.55	1.51
Maximum,	2220		
Actual Sv	2200		
Asv	1712		
dia	12		
legged	16		

Formwork design for transfer floor beam

Design parameter:-

			150mm
L2 floor slab thickness (S3) =			thk
Beam size	Width	(W)	0.850
	Depth	(D)	3.000
Slab span (S) (m)			30.000

Scaffolding Spacing

Calculation of working loads

Beam load	kN/m	61.200
Slab load	kN/m	97.944
Construction load	kN/m	60.000
(Allow 2kN/m2)		
Therefore,		
Total distributed working load		219.144
	kN/m	
Allowable scaffolding spacing(m)		0.228
(Using 50kN/frame for safe working load)		
Therefore, Scaffolding spacing(m)		0.200

Selection of size of timber joist for beam support

Span of timber joist = 1.219m

Uniformly distributed load	43.829
over 1.219m span of HW	

Timber joist (kN)	<57.3
Therefore, Hardwood sawn timber to be used	200mmx100mm

Rafter selection

Scaffolding span (m)	0.200
Using 100mmx50mm Hard wood sawn timber	
	~
Safe working load (kN) (Prorated from table)	9.5kN
No of Rafter	6
Space between rafter c/c (mm)	141.67

Beam soffit formwork and thickness of plywood selection

Load intensity	=	1.0*24	=	24.00	kN/m2
Construction load			=	2.00	kN/m2
Total working load			=	26.00	kN/m2

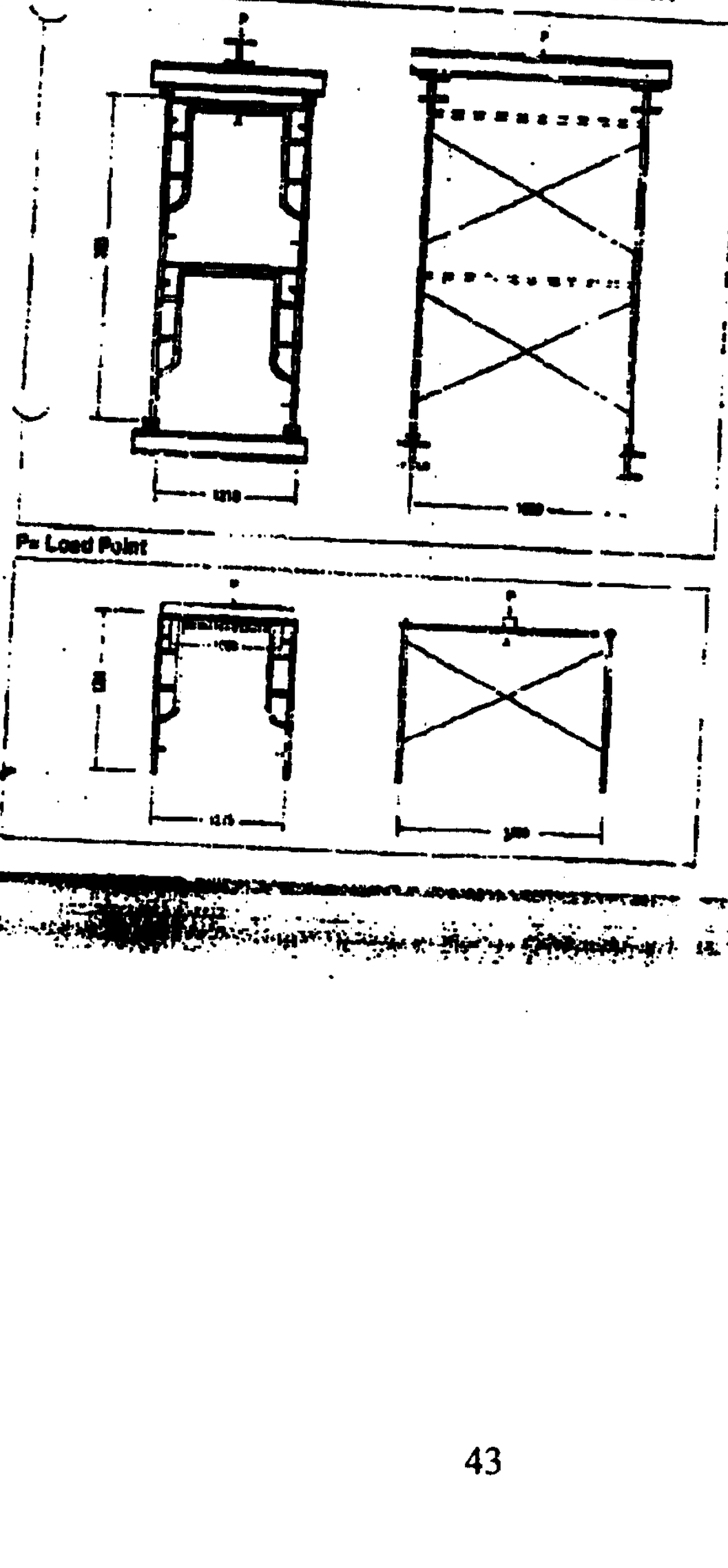
Base on the deflection vs Load intensity table of the plywood, we suggest to use 12mm thick waterproof plywood to be supported at 140mm c/c or less, the deflection shall be less than 1.0mm.

JAMBIN technical data

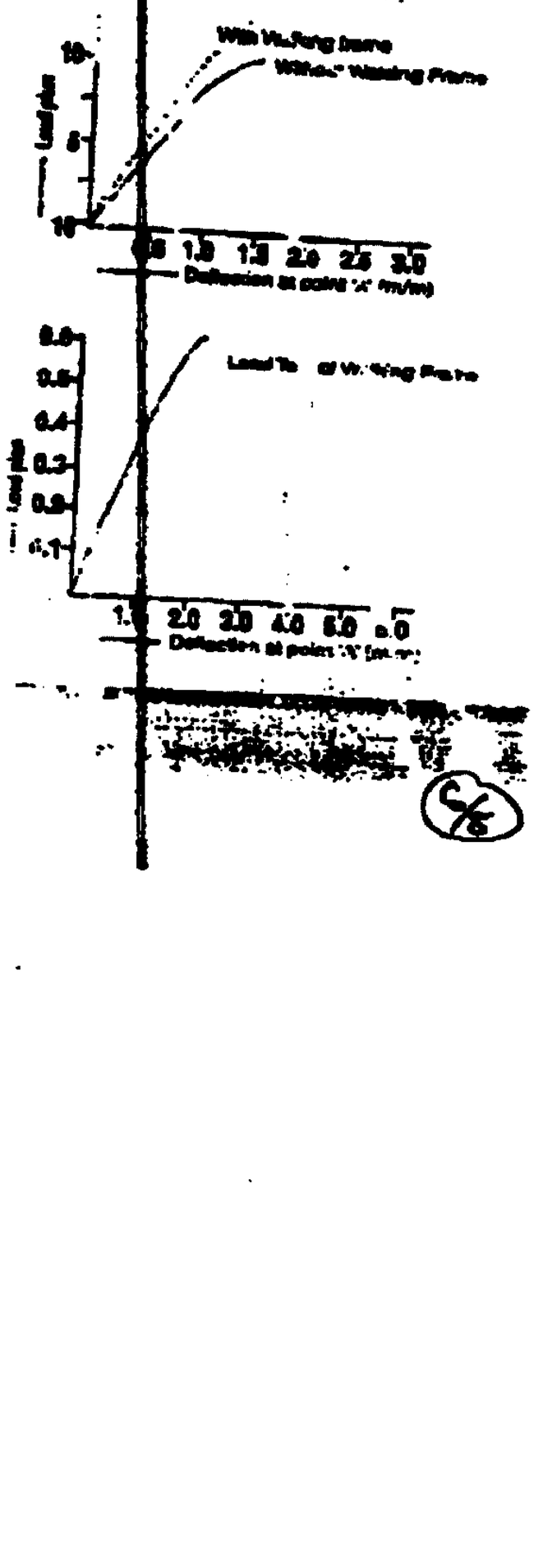
Strength of frame depends on positions where compressive load is being applied.

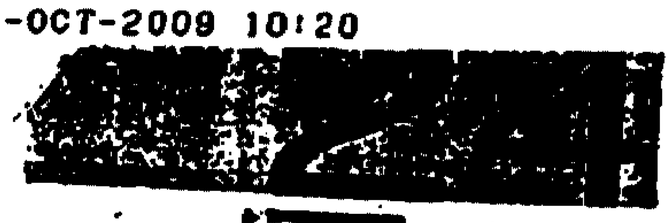
Point of load	↓ ↓	↓ ↓	↓ ↓	↓ ↓	↓	↓
Max load per frame P max	10(t)	9.1	7.5	6	3	2.25
Allowable load	5(t)	3.8	3	3	1.2	1

Note: For load point, square pipe material 100 mm × 100 mm is used.

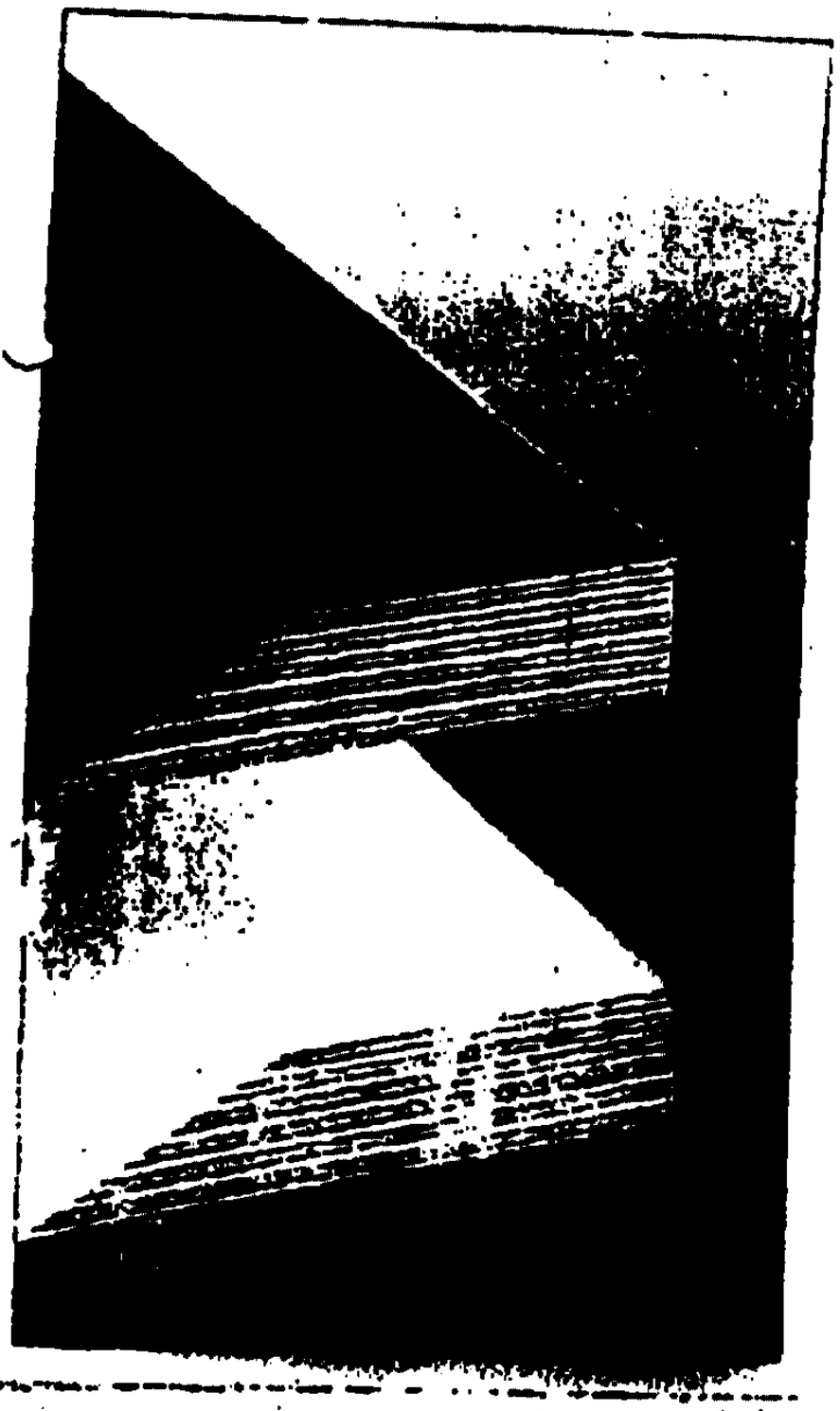


Jambin Di[illegible] has ... weight, a the System ... Tour for Scaffolding - Stainless and ... by the Faculty of Civil Engineering, ... (May 2nd, 1997)

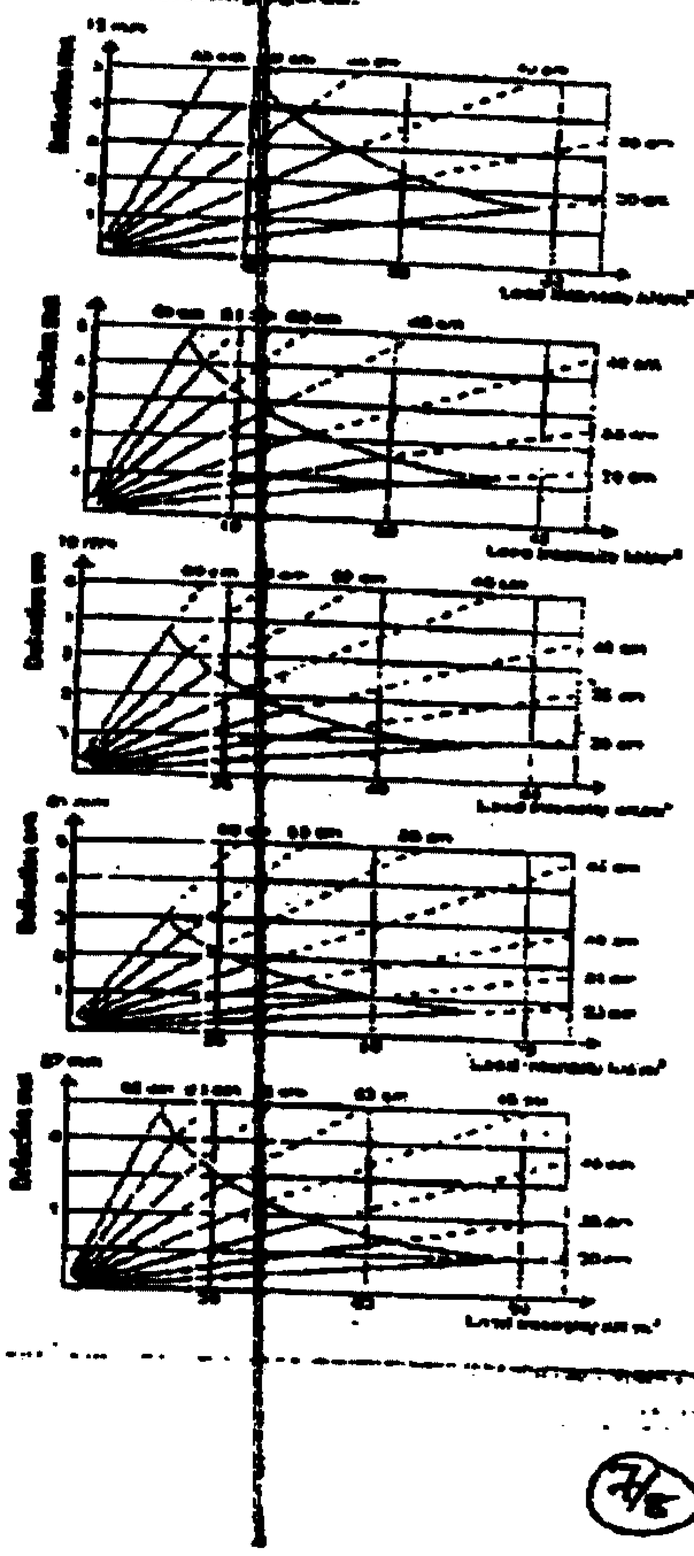




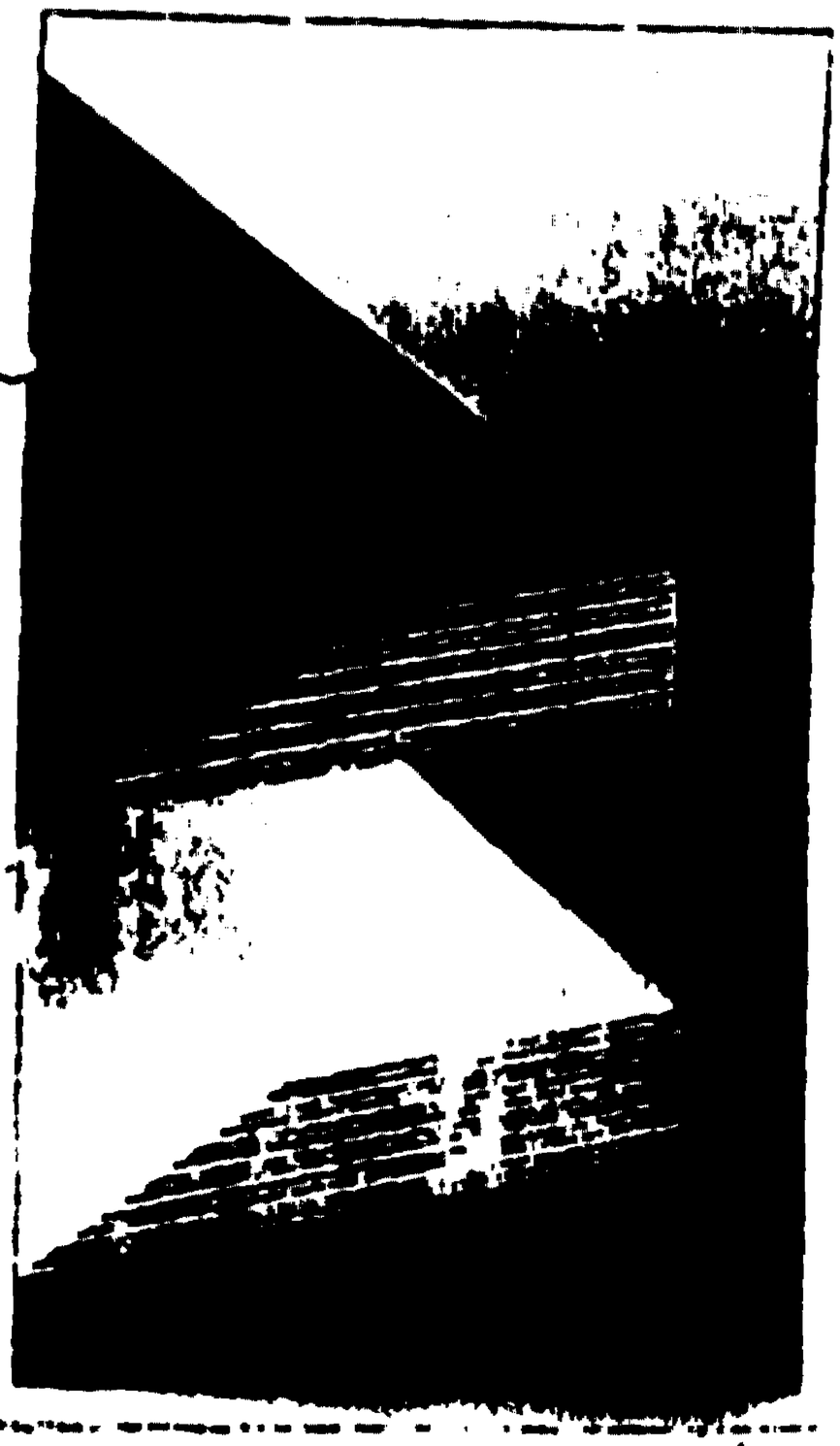
JAMES plywood & timber as support data



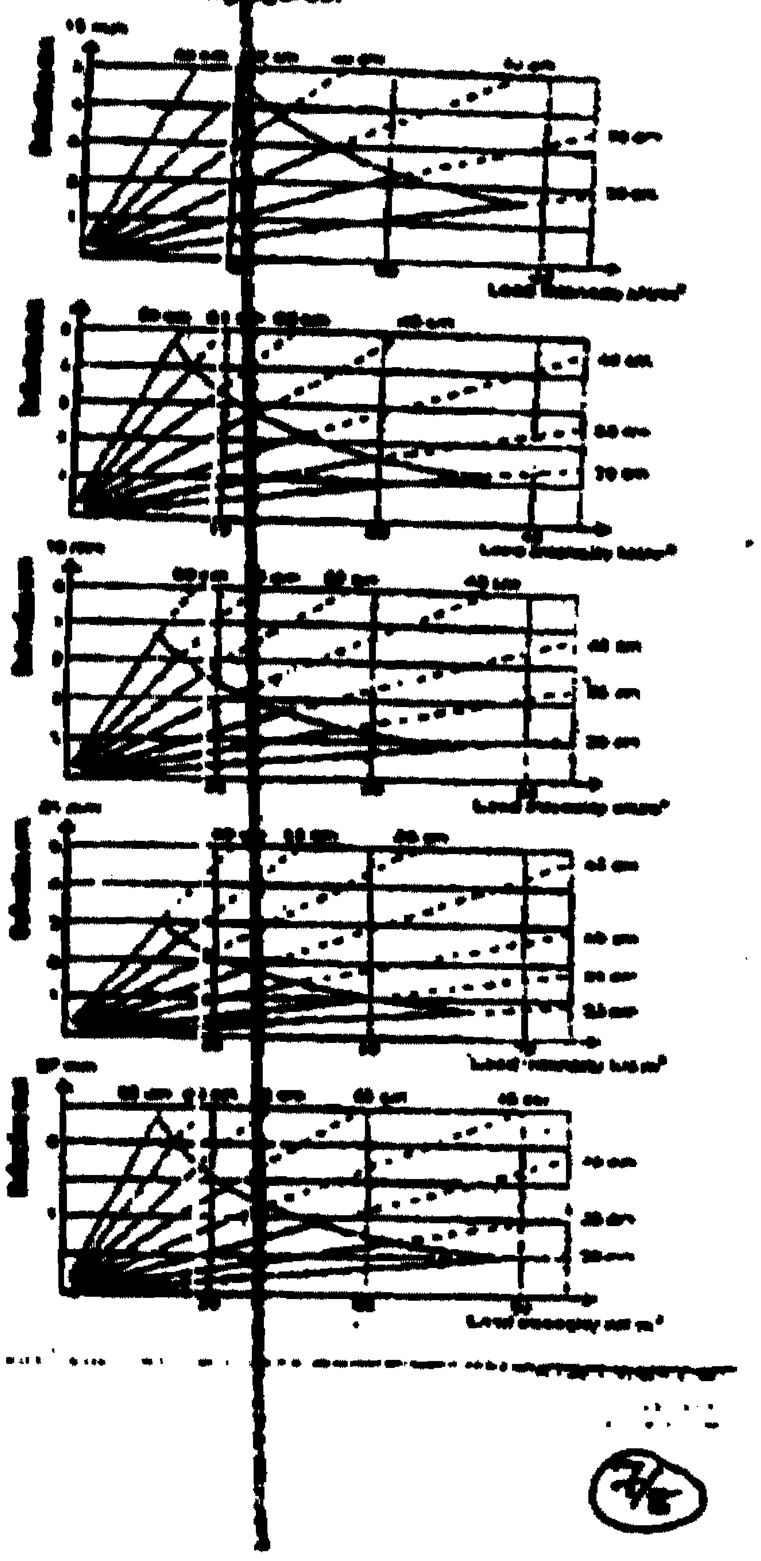
The maximum deflection of Wisaform panels between 300...600mm spans with an evenly distributed 0...90 k N/m² load is shown in the following figures.



plywood & timber as support data



The maximum deflection of Wisaform panels between 300...600mm spans with an evenly distributed 0...50 t/m² load is shown in the following figures.



plywood & timber as support data

Plywood

Sheets of plywood to be parallel to span and continuous over at least two spans. This is suitable for waterproof structural plywood in accordance with Australian standards, stress grade F8 or better.

Plywood

Span mm	Load Intensity kPa					
	2.0	3.0	4.0	5.0	6.0	7.5
300			7 mm THICK PLY			
400						
450			12mm THICK PLY			
600			17 mm THICK PLY			
750						
900						

Concrete Slab Loading

Span mm	Slab Thickness mm											
	75	100	125	150	175	200	225	250	275	300	400	450	600
300	4.7	4.5	4.5	5.4	6.1	6.8	7.5	7.5	8.2	8.8	10.5	11.3	13.4

Seasoned building grade oregon (stress grade F7) used as width supports for concrete.

Span mm	Slab Thickness mm						
	75	100	125	150	175	200	225
75 x 50	8.0	8.0					
100 x 50	6.0	4.8	4.0				
100 x 75	7.5	6.0	4.8	3.8			
125 x 75	11.3	9.0	6.7	7.0	5.8		
150 x 75	17.6	14.1	11.7	10.0	8.6	7.2	
150 x 100	26.4	18.8	14.8	13.4	11.7	8.6	7.8
175 x 75	26.4	21.1	17.6	15.1	13.2	10.0	10.0
175 x 100	39.2	31.4	27.7	25.0	20.0	15.0	13.6
200 x 75	38.1	30.5	25.3	22.0	19.7	17.6	15.6
200 x 100	57.3	47.8	37.8	33.0	29.7	26.4	20.4

Seasoned unidentified building grade hardwood (stress grade F14) used as width supports for concrete.

Span mm	Slab Thickness mm						
	75	100	125	150	175	200	225
75 x 50	4.8	4.7	1.8				
100 x 50	12.5	9.4	4.4	3.2			
100 x 75	18.7	9.8	8.8	6.8	3.7		
125 x 75	18.8	18.8	12.5	9.8	7.3	5.7	
150 x 75	28.6	22.5	18.8	16.4	14.6	9.8	8.8
150 x 100	39.1	39.8	33.0	31.0	14.7	13.2	10.7
200 x 75	4.14	40.8	33.8	28.1	25.4	20.8	16.8
200 x 100	57.7	54.8	46.1	38.8	33.8	30.1	26.4
175 x 75	41.8	40.8	47.5	38.8	33.1	29.8	26.7
2x ? x 100	83.9	68.8	58.8	54.8	76.8	67.8	59.9

To obtain safe working loads for other types of hardwood multiply loads given in table above by appropriate factor in accordance with AS 1720 e.g. Unidentified green hardwood - 0.61 Seasoned Jarrah structural grade 2 - 1.21.